The TREND IN ENGINEERING

at the University of Washington

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IMPEDANCE TRANSFORMERS FOR COAXIAL LINES

THE EFFECT OF PARTICLE SIZE ON CONTROLLED PROCESS OF CRYSTALLIZATION

AN ENGINEERING APPROACH TO REPORT WRITING

STRAIGHTENING STRUCTURAL MEMBERS IN PLACE

PEANUT PROTEIN ENRICHMENT TO IMPROVE PEANUT-MEAL GLUE

October, 1952

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THE ENGINEERING EXPERIMENT STATION

WHITEHEAD ON THE FUNCTION OF STUDY

THE FUNCTION OF THE STUDY of a subject is not so much to produce knowledge as to form habits. It is its business to transmute thought into an instinct which does not smother thought but directs it, to generate the feeling for the important sort of scientific ideas and for the important ways of scientific analysis, to implant the habit of seeking for causes and of classifying by similarities. Equally important is the habit of definitely controlled observation. It is the besetting fallacy of over-intellectual people to assume that education consists in training people in the abstract power of thought. What is important is the welding of thought to observation. The first effect of the union of thought and observation is to make observation exact. You cannot make an exact determination of the passing phenomena of experience unless you have predetermined what it is you are going to observe, so as to fix attention on just those elements of the perceptual field. It is this habit of predetermined perception and the instinctive recognition of its importance which is one of the greatest gifts of science to general education. It is here that practical work in the laboratory, or field work . . . is so important. Such work must be made interesting to obtain the proper engrossment of attention, and it must be linked with general ideas and with adequate theory to train in the habit of predetermining observation by thought. Every training impresses on its recipient a certain character; and the various elements in the general education must be so handled as to enrich the final character of the pupil by their contribution. We have been discussing the peculiar value of science in this respect. It should elicit the habit of first-hand observation, and should train the pupil to relate general ideas to immediate perceptions, and thereby obtain exactness of observation and fruitfulness of thought. I repeat that primarily this acquirement is not an access of knowledge but a modification of character by the impress of habit."

—"Science in General Education," from *Essays in Science and Philosophy* by A. N. Whitehead, 1948, Philosophical Library, Inc., New York.

THE ENGINEERING EXPERIMENT STATION of the University of Washington was established in December, 1917, to coordinate investigations in progress and to facilitate the development of engineering and industrial research in the University. Its purpose is to aid in the industrial development of the state and nation by scientific research and by furnishing information for the solution of engineering problems.

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(2) to undertake extended research and to publish reports on engineering and scientific problems;
(3) to provide opportunities for graduate engineers to conduct research under conditions that will most effectively prepare them for professional service.

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2. Chemical Engineering, Industrial Chemistry
3. Civil Engineering
4. Electrical Engineering
5. Forest Products
6. Geology
7. Mechanical Engineering
8. Mining, Metallurgy, Ceramics
9. Physics Standards and Tests

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October, 1952

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at the University of Washington

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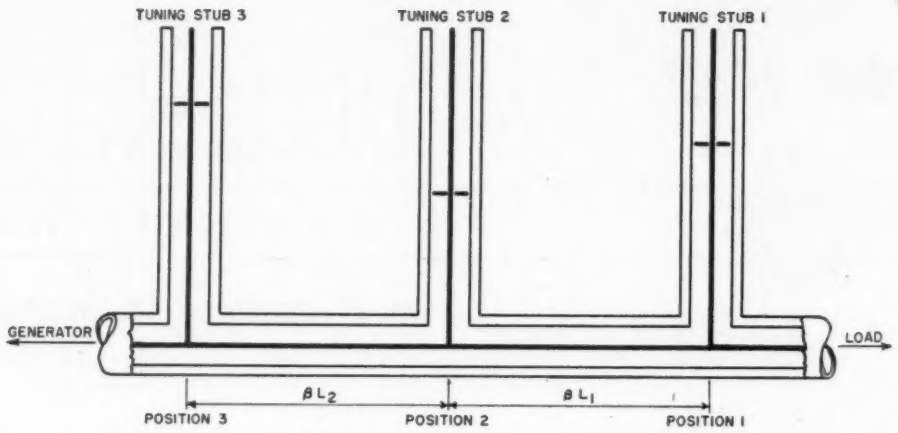

FIG. 1

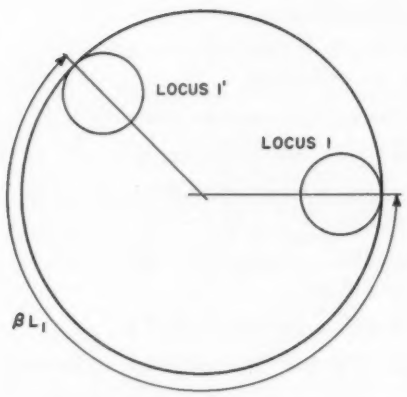

FIG. 2

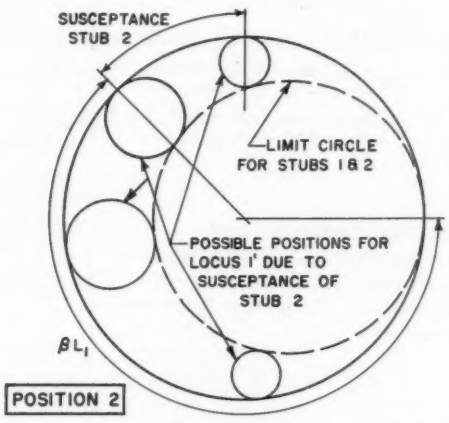

FIG. 3

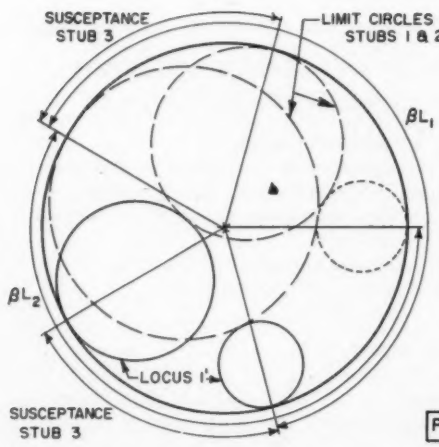

FIG. 4

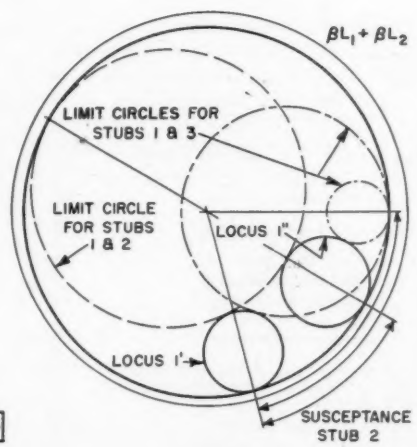

FIG. 5

COAXIAL-LINE IMPEDANCE TRANSFORMERS*

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Junior Research Engineer, Engineering Experiment Station

L. D. Barter

Although the analysis of coaxial - line impedance transformers, particularly the double-stub variety, is an old story, some of the ideas resulting from the necessity to build triple-stub transformers for our own use seem worthy of distribution. The operation of a double-stub transformer is presented in this report from a viewpoint which is readily extended to include triple-stub impedance transformers.

An analytical solution for a triple-stub transformer is difficult and cumbersome because this type of impedance transformer includes so many variables. A graphical analysis is more useful because it lends itself to showing trends and singular regions. The following method will consider the effect of one and two stubs and show graphically how the tunable region is determined. Then the effect of a third stub on the tunable region will be shown. When the tuners are used to match a load to a generator in order to deliver maximum power, the tuning paths or loci on a Smith chart are related to the indications of a power meter.

Figure 1 illustrates a transmission line with three tunable stubs between the load and the generator. For the general case let the load, referred to position 1, be

$$y=a+jb,$$

where a is any positive conductance and b is any positive or negative susceptance. The admittance y can be shown on a Smith chart. Assume that the stub tuner can add any positive or negative susceptance. The locus of points resulting from tuning of stub 1 will be a constant conductance circle such as locus 1 in Fig. 2. Now the effect of tuning stub 1, when referred to another position, such as at stub 2, will be a locus circle of the same diameter but the point of tangency to the zero conductance circle will be rotated through an angle corresponding to the electrical distance (βL_1) between the two stubs. This relation is shown by locus 1′ in Figs. 2 and 3.

Since stub 2 can add only a susceptance, any point on locus 1′ in Fig. 3 can be shifted on a constant conductance circle. Hence all possible transformed admittances are contained in the region bounded by the zero conductance circle and the conductance circle which is tangent to locus 1′. Let this latter circle be called the limit circle, for it limits the tunable and non-tunable regions of a two-stub tuner. It is impossible to transform the admittance y into any admittance within this limit circle with a two-stub tuner.

Consider now what factors determine the size of the limit circle. If the diameter of locus 1 in Fig. 2 had been larger, corresponding to a smaller load conductance, the limit circle would have been smaller. Also if the distance between the stubs had been closer either to one-half wavelength or zero wavelength, the limit circle would have been smaller. A large conductance in the load and a spacing of ¼ wavelengths between the stubs correspond to the worst tuning conditions for a two-stub tuner.

Any admittance in the region outside the limit circle can be attained by adjustment of stubs 1 and 2. It can be shown that the effect of stub 2 on the tuning loci of stub 1 is to change the size and position of the locus 1′ in Fig. 3, and that the loci are still circles.

Since all points on locus 1′ move along constant conductance lines when the susceptance jm is added, locus 1″ must be tangent to both the zero conductance circle and the limit circle. This means that locus 1″ could also be obtained from the result of a load admittance different from y, acted upon by the susceptance of stub 1 with a different length of line between the stubs. Hence one of the effects of tuning stub 2 changes the apparent length of line between stubs 1 and 2. This apparent change in length of line is equal in angle to the polar angle between points a and a' in Fig. 3, which is the susceptance $m_{a'}-m_a$ obtained from the edge of the Smith chart.

Rotating the pattern in Fig. 3, as shown in Fig. 4, by an angle corresponding to βL_2 will show the tuning loci of stubs 1 and 2 but will refer them to position 3. There will be two ways of determining the loci for three-stub tuners, but both ways will have in common that two stubs of a three-stub tuner will be analyzed as a two-stub tuner, and then the effect of the third stub will be shown.

When stubs 1 and 2 are taken as the two-stub tuner, the tuning locus referred to position 3 will be as shown in Fig. 4; as before, the broken circle is

*Abridged by the author from E. E. Department Report No. 5 to the Office of Naval Research, June 30, 1952.

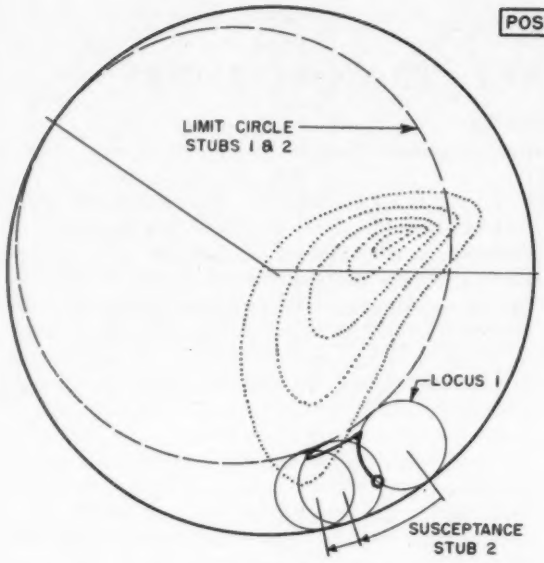

FIG. 6

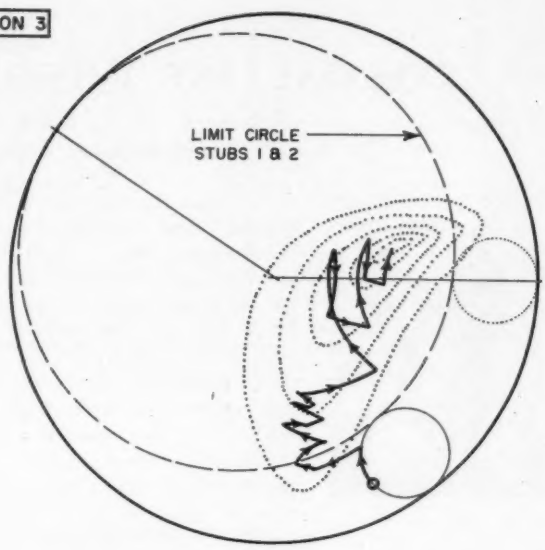

FIG. 7

the limit circle for stubs 1 and 2. Now the effect of stub 3 on the limit circle can be found, and hence the tuning region of the three stubs can be determined. Since the limit circle is a constant conductance circle when referred to position 2, its position and size can be changed in the same way as locus 1′ in Fig. 3 was moved. Therefore adding a susceptance in stub 3 will cause the limit circle to rotate and change in size so that it will be tangent to the zero conductance circle and the dotted circle as shown in Fig. 4. And since the size of the limit circle can be decreased to zero, the region of admittance to which the triple stub tuner can transform a load admittance increases to include all possible values.

Next assume that stub 2 is adjusted so that it has zero susceptance. Then the tuning loci will be identical to a two-stub tuner with a spacing of $(\beta L_1 + \beta L_2)$ as shown in Fig. 5. Stub 1 will transform the admittance around the locus 1′ circle while the "dash-dot" circle will be the limit circle for stubs 1 and 3. But since stub 2 can change the effective length between stubs 1 and 3, it can shift the position of locus 1′ and thus control the size of the limit circle for stubs 1 and 3. For example, assume stub 2 adds a negative susceptance. Locus 1 will then move to locus 1″ which is closer to the point of infinite admittance, as in Fig. 5. Since the limit circle for stubs 1 and 3 must be tangent to locus 1″ and also tangent to the zero conductance circle at the point of infinite admittance, the limit circle can be made vanishingly small by adjusting stub 2 so that locus 1″ is also tangent at this point.

The best spacing between the stubs of a triple stub transformer can be determined by considering the factors which affect the size of the limit circle. Referring to Fig. 5, if $(\beta L_1 + \beta L_2)$ had a value which would place locus 1′ near the point of infinite admittance, the untunable region would be inherently small. This result would be true even though y had a large conductance value, which means a small diameter circle for locus 1′. But transforming y to a small admittance would require a fairly large value of susceptance in one or more of the stubs, implying an extremely large standing wave ratio between stubs. If $(\beta L_1 + \beta L_2)$ had a value which would place the tangent point of locus 1′ at the zero admittance point, a large susceptance in at least one stub may be required to transform y from a large value at position 1 to a large value at position 3. But $(\beta L_1 + \beta L_2)$ equal to an odd eighth of a wavelength, such as $\frac{3}{8}$, $\frac{5}{8}$, or $\frac{7}{8}$, would be a good compromise between the two extremes, in that transforming any admittance y to a conductance with zero susceptance would not require extreme values of susceptance in any stub.

Knowing the tuning loci on a Smith chart does not help directly in practical applications since the common indicators do not plot the loci on Smith charts. Hence a correlation between an instrument used for indicating power match and the tuning loci is necessary. Contour lines representing constant power are drawn upon a Smith chart in Fig. 6. As a tuning path crosses these lines a power indicator would increase and decrease as an altimeter carried

over a ridge by a person reading the elevation. The point of optimum match would then correspond to the top of the hill.

In this particular analogy the person would not be able to see which direction was up, but must rely only upon the magnitude of the reading of his instrument. Hence, after walking in a straight line and obtaining a maximum, he must then change his direction of travel to climb higher on the hill and again maximize the reading. The problem in tuning an impedance transformer is similar. After observing a maximum in the power indicator, another tuning path must be chosen to further maximize the reading. Figure 6 illustrates this point. Stub 1 is tuned until a maximum is indicated. This maximum will occur where the path crosses the ridge. Notice at the maximum point that the tuning path is tangent to a contour. Therefore, in this region, the nearer the new path is perpendicular to the old one, the more rapid will be the rise of the power indicator.

Referring again to Fig. 6, continual retuning of stubs 1 and 2 would result in a maximum at the point where the limit circle is tangent to the contours. Since both tuning paths of stubs 1 and 2 are tangent to the contours no further increase is possible in this region. In fact, a considerable displacement of stub 2 would be necessary in order to approach the other possible maximum shown in Fig. 6 where the ridge crosses the limit circle. This is a limitation already recognized in a two-stub transformer. As will be shown later, a three-stub transformer will always progress "up the hill" to the peak with the exception of a very few limited cases.

Path constructions similar to those described for Fig. 6, but for a three-stub tuner, are shown in Fig. 7 for transforming a load admittance to an optimum generator admittance. Stub 1 was adjusted first to give a maximum in the power indicator, then stub 2 was adjusted, then stub 3, and the sequence repeated. The path will progress up the hill since rarely will all tuning paths and the contours be tangent at the same point. But note that after several adjustments, the increments become less and less.

Although this procedure would eventually reach the top of the hill, a quicker method would be to adjust the stub past the maximum as shown by the power indicator, and as is shown after the fourth sequence in Fig. 7. But when using the quicker approach, one might ask, "How do you know when the top of the hill was passed?" This condition is also shown in Fig. 7. Adjusting stub 3 over the top of the hill will be shown in the next sequence by a lower maximum. The tuning paths would then come back up the other side of the hill. As is commonly known, this oscillating approach requires fewer total adjustments. And if there is only one hill, the sequence will be a converging one.

Hence, by adjusting the three stubs in sequence and observing a power indicator, the point of optimum power match can be accomplished.

A more detailed discussion showing the construction of the tuning paths, as well as tuning limitations of the stub tuners is covered in the author's original report to the ONR.

Ceramic Society Holds Regional Meet

THE FIFTH ANNUAL PACIFIC COAST regional meeting of the American Ceramic Society was held on the campus October 16-18. Nearly fifty technical papers and discussions highlighted the conference, which took place in the area farthest removed from any previous A. C. S. activity. A number of University of Washington faculty and campus personnel took part in the program.

Technical program chairman was Hal J. Kelly, metallurgical engineer of the Northwest Mines Experiment Station (U. S. Bureau of Mines). Mr. Kelly also presided over the session devoted to white wares. Howard McDonald, Instructor in Mineral Engineering, was Chairman of the "General Interest" session. Appearing on this program were J. I. Mueller, Assistant Professor of Mineral Engineering, who read a paper on "Some Applications of X-ray Diffraction in Ceramic Research," and Jack Pittman, U. S. Bureau of Mines research fellow, who discussed "Temperature Control Equipment for Differential Thermal Analysis Using On-Off Power Input."

Professor Mueller was also co-author of two other papers, "Analysis of Iron in Raw Materials," (Glass Session) with R. J. Campbell, Chemical Engineer, U. S. Bureau of Mines, and "Use of Alkalie-Fluoro-Silicate Glasses for Enamelling of Aluminum," (Enamels Session) with E. C. S. Rao, graduate student.

R. E. Rockwell, Instructor in Ceramic Engineering, appeared on the Design Session program with "Contemporary Design in Ceramics."

Representatives of state and industrial groups from many parts of the United States and Canada attended and took part in the Conference.

THE EFFECT OF PARTICLE SIZE ON CONTROLLED CRYSTALLIZATION PROCESS

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N. R. Mukherjee

Introduction

In a crystallization process the general trend is to manufacture, by controlled operation, pure crystals of uniform size and shape. One might, for example, seed a supersaturated solution and control the operation for the subsequent growth of the seed crystals to a desired uniform size and shape. A number of factors affect the growth of crystals, e.g., rates of cooling and stirring, the viscosity of the solution, the interfacial tension between crystals and the solution, the nature of the solute-solvent system, the particle size of the seeds, the mechanical design of the crystallizer and its accessories, etc. The effect of particle size on the supersaturation and the controlled crystallization will be the subject of discussion in this paper.

Critical Size of a Crystal

The solubility of a substance increases as its particle size decreases. In general a little increase in solubility is observed when the average radius of the particles is of the order of 10^{-3} cm. Particles of bigger size than this may be considered to have practically no effect in changing the solubility. Since Miers' metastable zone is bounded on one side by the normal solubility curve (where radius of the particle is bigger than 10^{-3} cm), the solubility curves of particles smaller than 10^{-3} cm lie in Miers' metastable zone.

In Fig. 1, let AB be the normal solubility curve, i.e., the equilibrium curve of the heterogeneous phase where the solid phase has the particles of radius greater than 10^{-3} cm, and let CD be the curve where the nucleation starts when the homogeneous solution is cooled. Though the curve CD is not as accurately

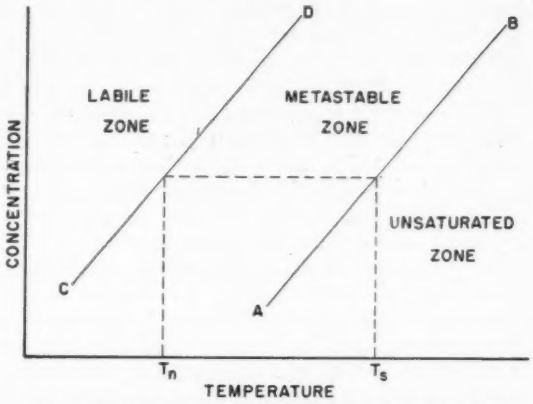

FIG. 1. TEMPERATURE CONCENTRATION RELATION FOR SOLUTE-SOLVENT SYSTEM

defined as curve AB, it represents the line of demarcation between the metastable and labile zones. For the same system the position of CD is dependent on the rates of stirring and cooling, presence of impurities, and crystalline structure of the solute (if any particular solute has more than one crystalline form). Miers' conception of the metastable zone in the supersaturated solution may be easily understood as defining conditions in which crystal-cell formation is negligible. At a supersaturation represented by CD, the fluctuation in local concentration may be sufficient to cause the formation of stable crystals of minute size which, under favorable circumstances, will grow to crystals of bigger size.[1] At this stage when crystals are just born, they are in equilibrium with the supersaturated solution and of size varying over some range governed by statistical mechanical laws. Assuming an average size, these crystals may be called crystals of "critical size," which is dependent on temperature of their formation and solid solute-solvent system. Since the solubility increases with the decrease of particle size, the curve CD may be called the solubility curve of the particles of critical size (radius=r^*).

Thermodynamical Treatment

The thermodynamical potential of the whole system consisting of solute elementary particles in the

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liquid (solvent) phase A (assuming solvent as a diluting agent) and the solid phase B (assuming spherical solid particles) can be expressed as

$$\phi = N_A\mu_A + N_B\mu_B + 4\pi r^2\sigma, \tag{1}$$

where $N_A+N_B=N=$total number of elementary particles as ions or atoms or molecules (notice the distinction between solid particles, i.e., tiny crystals, and elementary particles, i.e., ions or atoms or molecules), μ_A, μ_B are chemical potentials referred to one elementary particle of the solute in the corresponding phase at a given temperature, and r is the radius of the solid particle having the interfacial surface energy per unit area σ.

Since the thermodynamic equilibrium of the system is determined by the equation $\delta\phi=0$, Eq (1) reduces to

$$\mu_B - \mu_A + 4\pi\sigma \frac{dr^2}{dN_B} = 0. \tag{2}$$

Now $N_B = \frac{4\pi r^3}{3v_B}$ where v_B is the volume occupied by each elementary particle in the solid phase and, therefore,

$$\mu_B - \mu_A + \frac{2\sigma}{r} v_B = 0. \tag{3}$$

As a limit, when $\mu_A \rightarrow \mu_B$, i.e., when the condition of ordinary equilibrium exists between two phases, $r \rightarrow \infty$. If the solution contains two types of solid particles of sizes r_1 and r_2 where 10^{-3} cm$>r_1>r_2>r^*$ and is saturated with both the types of particles, we get from Eq (3)

$$\frac{r_1}{r_2} = \frac{\sigma_1}{\sigma_2}, \tag{4}$$

where σ_1 and σ_2 are the surface energies of the solid particles of radii r_1 and r_2, respectively. Since $r_1>r_2$, $\sigma_1<\sigma_2$ and, therefore, Eq (4) fails. This leads to the conclusion that a solution saturated with solid particles of size r_1 cannot be saturated with solid particles of size r_2. Therefore, if we start with these two types of small solid particles, and the solution is kept at a temperature which is the saturation temperature corresponding to particles of size r_1, the solid particles of size r_2 ($r_2<r_1$) will dissolve and make the solution supersaturated with respect to those of size r_1, and the latter will grow bigger. The dissolution of solid particles of size r_2 will continue until the solution is saturated with respect to the reduced size of r_2. If the number n_{r_2} of size r_2 is much greater than that of n_{r_1} of size r_1, the former particles may survive after reaching a certain reduced size greater than the critical size r^*, due to the fact that the solution will be saturated with respect to those particles of reduced size. If r_2 is not sufficiently greater than r^* and n_{r_2} is slightly greater or equal or less than n_{r_1}, there is practically no chance of survival of n_{r_2} particles prior to their reduction to embryonic size less than the critical size r^*. This embryonic size is, in general, maintained by the density fluctuation in the liquid phase.[1] The population of the embryonic size is characterized by a steady distribution with respect to their size.[2] This distribution is determined by Boltzmann's formula,

$$n_{r_0} = Ce^{-\Delta\mu(r_0)/kT}, \tag{5}$$

where k is the Boltzmann constant, n_{r_0} is the number of such embryos of radius r_0, and C is the proportionality constant, which as long as the number of embryos remain relatively small is of the order of N. If n_{r_2} particles are reduced to such embryonic size, they will form crystal nuclei of critical size r^* when the superaturation or supercooling reaches the curve CD. (The "wall effect"[3] and the "surface effect" of the crystals already present in the solution are neglected.) That is to say, we are back to the same condition of nuclei formation by supercooling a homogeneous solution.

Nuclei Formation and Effect of Viscosity

The quantitative formulation of nuclei formation is perhaps best approached from the theory of condensation of superaturated vapor, bearing in mind that there is an essential difference between the formation of liquid drops of spherical shape and building up of a geometric shape bounded by plane surfaces. According to Becker and Döring,[4] the rate of nucleation, Z, (number of nuclei formed per unit time, per unit volume at a temperature T) is

$$Z = C\exp\left[-\frac{1}{kT}(E+W)\right], \tag{6}$$

where E is the activation energy of diffusion, W is the work required to form the surfaces of nuclei, and C is a constant. This expression assumes the critical size to be, to a close approximation, a sphere and indicates that the probability of a nucleus of critical size being formed is dependent on both the diffusion term and the work term. Tammann[5] and others[6] have shown that for the curve Z vs. T, the value of Z is negligible up to a certain degree of supercooling (T_s-T_a) and then increases sharply to a pronounced maximum and decreases again, (T_s)

being the temperature at which the solution is saturated with respect to solid particles of size greater than 10^{-3} cm, and T_n, the temperature at which nucleation starts. (See Fig. 1). The viscosity[7] of a liquid as a function of temperature is represented by an equation of the form $\eta = De^{E/\kappa T}$, with an approximately constant coefficient D. From the above relation and Eq (6) it can be concluded that the decisive role in nuclei formation is played by the viscosity of the solution and the work required to form the surfaces of the nuclei. The degree of supersaturation, $(T_s - T_n)$, is great for those which have high values of η and W and vice versa.

It has been shown that if there are two types of solid particles of sizes r_1 and r_2 ($r_2 < r_1$) in the solution which is saturated with respect to those of size r_1, the solid particles of size r_2 will dissolve. Provided that n_{r_2} is sufficiently greater than n_{r_1}, the rate of increase in supersaturation will be greater than the rate of removal of supersaturation, and there is a chance that the solution will be carried to the boundary line between Miers' metastable and labile zones and that fresh nucleation will take place. In an ideal case if the "wall effect" and the "surface effect" of the crystals present in the solution are neglected, and if $r_1 > 10^{-3}$ cm $> r_2 > r^*$, the values of r_1 and r_2 will have no effect on the value of $(T_s - T_n)$. In practice, however, "wall effect"[3] and "surface effect" of the crystals present in the solution are of considerable importance in the determination of T_n. For a particular solution and a small range of temperature, "wall effect" of the container may be assumed to be constant. For solid particles of a size smaller than 10^{-3} cm, their surface effect will increase with their decreasing size and therefore fresh nucleation will take place at a higher temperature or lower concentration than that in the case of nucleation from a homogeneous solution. Under these circumstances if r_1/r_2 increases (where $r_1 > 10^{-3}$ cm $> r_2 > r^*$) but r_2 is constant, $(T_s - T_n)$ will be constant; if r_1/r_2 increases but r_1 is constant, $(T_s - T_n)$ will decrease. If both r_1 and r_2 are between the range 10^{-3} cm and r^*, and if r_1 is fixed but r_1/r_2 increases, $(T_{s_1} - T_n)$ will decrease, where T_{s_1} is the saturation temperature with respect to the solid particles of size r_1; if r_2 is fixed, but r_1/r_2 increases, $(T_{s_1} - T_n)$ will increase. The latter condition is also valid when $r_2 = r^*$. For a given solution and experimental conditions, $(T_s - T_n)$ is constant within the allowance of statistical mechanical laws if r_2 is fixed and/or equal to r^*, and r_1 is greater than 10^{-3} cm.

Conclusions

From the foregoing discussion the following conclusions may be drawn for a controlled crystallization process:

1. The size range of the seed crystals should be as small as possible.
2. Fresh nucleation in the supersaturated solution during the growth of the seed crystals is a serious drawback so far as the production of crystals of uniform size and shape is concerned. Therefore, the degree of supersaturation should be kept at an experimentally determined safe limit to avoid any fresh nucleation.
3. The rates of stirring and cooling should be kept constant.
4. The crystallizer should have a minimum number of edges, corners, and sharp points to eliminate the "wall effect."

The writer is investigating other factors for the controlled crystallization process on which he will report at a later date.

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ROBBINS STUDIES STEAM EQUIPMENT IN EAST

F. D. Robbins, Assistant Professor of Electrical Engineering, spent the summer at the Research and Development Center of the Babcock and Wilcox Company in Alliance, Ohio, investigating combustion of fuels in the Center's 5-foot cyclone furnace. Low-rank coals, abundant in the state of Washington, are high in ash, moisture, and volatile content, thus being adapted to use in a cyclone furnace. The unit was also investigated for its adaptability for use in an integral power network with possible wide ranges in load requirements.

Professor Robbins, whose article, "Steam Plants and the Northwest Power Shortage," appeared in *The Trend* for October, 1951, and January, 1952, was one of 18 representatives of U. S. universities invited to carry on research at one of the Babcock and Wilcox centers. He has recently been appointed to the Regional Advisory Council of the Bonneville Power Administration.

Toll-Road Research Assigned to University

A NEW HIGHWAY RESEARCH PROJECT to investigate conditions which justify toll-road charges, and the resultant repercussions on local roads and the balance of the highway system, has been assigned to the University by the Washington State Highway Research Council.

The first annual report of the Council, recently released, outlines the five projects already under way or proposed as follows:

Project I. Highway Classification

This project which has been carried on during the past year jointly by the State College of Washington and the University of Washington, will report a survey of the state highway system in its relation to county roads and city streets with "the purpose of establishing criteria for measuring the merit of any proposed change in the system." Roads are classified according to the extent to which they contribute to agricultural, industrial, commercial, and recreational interests of more than local extent. This project is sponsored by the Joint Fact-Finding Committee on Highways, Streets, and Bridges, Washington State Legislature, to provide a factual basis for legislative action.

Project II. Natural Resource Roads

Research Agencies:
Washington Department of Conservation and Development
Washington Department of Highways

Study of the extent to which public interest is involved in the growth and prosperity of the forest products industry and the size of the logging truck which would provide the greatest economy in log transportation over public highways is being conducted by the Institute of Forest Products, a division of the Department of Conservation and Development. The State Highway Department is inquiring into the increase in road maintenance cost to the state incurred by use of the optimum weight vehicle. These investigations may later be extended to cover means of designating and administering such roads. This project was requested by the Natural Resource Road Committee, Pacific Logging Congress.

Project III. Use of Agricultural Soil Maps in Road Building

The State College of Washington will carry on this study to collect, organize, and interpret data available from state and federal agencies in the fields of soil conservation, agronomy, reclamation, and plant industry. The report will supplement present soil investigations undertaken by state highway engineers and will be of even greater help to county engineers who lack laboratory facilities. The Washington Department of Highways is the sponsor.

Project IV. Application of the Washo Test Data to Washington Roads

This project was planned to interpret data obtained from the test road being constructed at Malad, Idaho, under the auspices of the Western Association of State Highway Officials, in terms of Washington climate, soils, and traffic, so that they may be evaluated for application to Washington roads and highways. The study, requested by highway user groups, is expected to provide invaluable information on the relationships between load, road, and subgrade.

Project V. Toll Roads in Washington

A study to provide some rules for the state of Washington regarding the traffic density needed to justify toll roads, and also the amount of traffic generated by freeway construction, has been assigned to the University of Washington. Increasing traffic volume requiring expensive standards of highway construction presents a problem of financing which user taxes are unable to meet. Sponsor is the Washington State Highway Commission.

The Washington State Council for Highway Research was set up by Governor Langlie in June, 1951, with R. G. Hennes, Professor of Civil Engineering at the University of Washington, as chairman. Other members of the Council and the groups they represent are as follows:

W. A. Bugge, State Director of Highways
Fred J. Dixon, District Engineer, U.S. Bureau of Public Roads
Fred J. Lordan, representing Highway User Groups
C. W. Martin, Commissioner of Public Works (Walla Walla), representing the Association of Washington Cities
E. B. Moore, Head, Department of Civil Engineering, State College of Washington
Fred Redmon, Chairman of Washington State Highway Commission
R. C. Watts, Executive Secretary, Association of County Commissioners.

An Engineering Approach to Report Writing

JAMES W. SOUTHER
Instructor in Humanistic-Social Studies

J. W. Souther

An analysis of professional report writing problems indicates in general the failure of the writers to design their reports for a particular industrial function. This is not a criticism of engineers; rather it is a criticism of the education they receive. Too many courses in technical writing reveal their origin in traditional composition courses; far too few bear any close relationship to actual industrial writing situations.

Most of the report writing courses—and, for that matter, most of the available texts—offer an abundance of suggestions regarding the finished product, describing it in detail, but ignore completely both the process by which it evolved and the relationship between the industrial function of the report and the final form which it will take. Yet these are the points at which most writers fail. To ask an engineer to design an amplification stage for a particular electrical control system without providing him with the factors of the problem would be considered foolhardy; yet this is precisely what is being done in many report writing courses. Assuredly, neither sound engineering designs nor effective industrial reports spring from a contextual vacuum.

In writing, as in engineering design, quality products depend upon:

(1) accurate and extensive analysis
(2) complete and thorough investigation
(3) detailed and purposeful design
(4) careful and ordered application

Analysis

The point of attack in both is the analysis of the problem: in report writing, determining the purpose of the report, the industrial role it is to play, and the audience to whom it is directed.

Purpose

The writer must realize that the purpose of his report is his first major consideration. He must recognize, for example, that a report directed toward a stricter observance of safety rules in a particular department will differ from one which reviews the actual observance of the present rules, and both of these will differ from one which aims at improvement and extension of the rules themselves. The first stipulates clearly and concisely what is to be done in the future; little mention of old practice is needed. The second includes a statement of past procedures and records the extent to which the rules have been followed or disregarded. In the third, a statement of recommended modifications and additions to past rules, made to insure future safety, is the essence of the report. For example:

Report I
Stricter observance of rules
1. Rules not observed
2. Future action regarding the observance of these rules

Report II
Survey of adherence to rules
1. Safety rules followed
2. Safety rules disregarded

Report III
Recommended rules
1. Old rules to be retained
2. Old rules to be changed
3. New rules to be added

Industrial Role

A report whose industrial role is one of reference use needs to be complete in all details since the material will quite likely be unfamiliar to the reader by the time the report is used—at least the immediate context from which the report sprang may long have disappeared, and personnel may also have changed.

At one concern, for example, a staff of chemists employed in the experimental laboratories were required to record their experiments and findings for reference use whenever the need arose. These reports, adequate at the time they were first submitted, later proved useless as references, for not only could the results not be clearly understood but some of the experiments could not even be repeated. At the time of writing, the experiments were fresh in mind; the writers were comfortably in the context of the situation and gave little thought to what the reader would require in order to understand the account when he came to it "cold," perhaps years later.

An example from another concern also reveals failure to consider the industrial role of the report. One of the engineers spent a great deal of time and energy in compiling a long report which was to be

constantly used for reference by non-technical personnel; yet his work was rendered almost useless because of its general "layout." After a table of contents, thumb tabs for the main sections, and an index were added, the report became both usable and valuable. The writer knew of these common devices but neglected them because he did not consider the *use* to be made of his report. He did not design his report to serve its particular industrial role.

Audience

In addition to purpose and industrial role of the report, the report writer must also take into account his audience. Not only must he consider the education and experience of the reader, since these factors will determine the amount of detail and the level of technical language and usage which he can safely design into his report, but he must also determine what is of *most importance to his reader*—what the reader *wants* from the report.

Investigation

Once the analysis is completed, the writer is faced with the task of investigating the problem. With the analysis as his guide, he plans his attack of the problem, gathers his data, and evaluates his material, selecting what he is to use.

Since the engineer is trained in the techniques of investigation, little need be said of them. It is necessary, however, that he be warned of the unnecessary work which results from failing to realize what is basic to the study. Often he wastes much time and labor gathering irrelevant information.

Plan of Attack

If the report is to be effective, the writer must determine what is of most importance to his reader and to the purpose of his report. He must determine whether facts, results, conclusions, or professional opinions are most vital to his industrial objective.

Competent engineers frequently fail to determine what is essential to the report which they must write. They fail to distinguish between the *important* and the *related*. Then, trying to play safe, they rush to cover *all phases* of the problem and often submerge what is important and what the reader wants to know in a mass of related but less important material, so as to defeat the chief purpose of the report.

Once the writer can distinguish between the elements of major and minor importance, he can then consider in proper perspective the task facing him. He can then form a tentative plan of attack based on a thorough analysis of his problem. He knows what he is attempting to do in his report; he knows what is of major importance; he knows what he must do in order to complete his report. With these in mind, he can plan his method of solving the problem and writing his report.

Gathering the Material

In gathering material, the engineer has little difficulty. Here he is quite at home. His technical training has usually made him particularly adept in gathering material. He should, however, make use of all printed indexes and bibliographies in an effort to discover what material is already available from other sources. The scope and number of these research devices is amazing, and the time-conscious report writer makes use of the available over-all view of the scientific, engineering, industrial, and governmental reports and publications furnished in indexes and bibliographies.*

Evaluation of Material

Proper evaluation and selection of material depends upon a knowledge of what is important to the purpose, industrial role, and audience of the report. Often, the results achieved, or the conclusions drawn, are of much greater importance to the industrial function of a report than are the facts and data from which they were obtained. For example, a report which is to determine whether or not capital is to be invested in a particular production process must emphasize results and conclusions, for it is on these that the financial decisions must be made. If a report is a weekly progress report, however, facts and data are of prime importance and conclusions are usually not included. In short, the evaluation and selection of material must be based on the specific requirements of the task at hand.

Design

After the material is gathered and evaluated, the writer faces the all-important task of arranging his material, of designing the report he is to write. He must realize that from the *many possible ways* of organizing his material, he must choose the *particular one* which he feels *best suits* his purpose, and such a choice, to be effective, must be based on a realistic analysis of the problem being faced. In other words, the report must fulfill its purpose, be useful, and have proper emphasis.

Fulfillment of Purpose

Success or failure depends upon the ability of a report to satisfy its industrial function, for the report must be organized so that the report accomplishes its purpose of clearly communicating to its audience the exact information desired. The writer must constantly keep in mind the objective of his report, the use to be made of it, and the requirements of the

* The best survey of this material available is to be found in a forthcoming McGraw-Hill publication, Vaughn and McClintock's, *Presenting Technical Ideas*. The authors have combined actual industrial experience with scholastic method to produce an outstanding survey of industrial and engineering indexes.

audience which will use it. He must realize, for example, that reference use requires broad and detailed coverage of all phases of the project. Periodic progress reports emphasize information related to the period of the report. Reports which place emphasis on recommendations are primarily concerned with his judgment regarding the project. In each case the report, to be successful, must meet the requirements of purpose, industrial role and audience.

Functional Organization

In addition to being clear and understandable, the report must be organized so as to be most useful to its readers. The growing demand for abstracts and summaries in industrial reports stems from this requirement. Results and conclusions, in most cases, are far too important to be placed only at the end of the report, and the alert report writer will place at least a summary of his findings near the beginning of the report. *One of the most difficult tasks of the report writer is to recognize that, more often than not, the order in which he gathered his material and reached his conclusions, or the order in which he conducted the tests, is not the most satisfactory arrangement for the report which covers them.*

Effectively designed reports also save the reader time by having all parts clearly identified through proper use of titles and subtitles. Sections of equal importance are given identical physical arrangement, and subordinate relationships are made obvious at a glance by their position on the page.

Emphasis

In order for a report to accomplish its purpose, the material must be given a perspective, an obvious internal relationship. Important material is given a fuller treatment than is the less essential. Items of special value are placed in a position of emphasis, usually near the beginning of a report. The use of attention-getting devices such as italics, capitalization, spacing, and location on the page are used to give items proper emphasis in an effective report. Stylistic devices, such as repetition and parallel construction, are used effectively by successful report writers to give emphasis to their ideas.

Application

The final stage of report writing consists of applying the determined design, checking it for effectiveness, and preparing the final product.

Applying the Design

Once the report is designed, the writer should write as rapidly as possible in order to give life and sparkle to his phrasing as well as to preserve the continuity of ideas which is often destroyed by constant rework and polishing during writing. During the first draft, he should pay little attention to the mechanics of writing, for these can be corrected later. Whenever in doubt about including information, he should include it, for it is a much easier task to cut a report than it is to expand one. If the report is long and complex, however, the writer may prefer to work on each part of the report separately, finishing each section before moving to the next.

Although the design has been determined, it should always be open to desirable modification. The writer should not feel that he is a slave to his plan.

Abstracts and summaries should be written last, for reading and outlining the report will provide the writer with the essential information.

Checking the Report

Upon completion of the first draft, preferably after some time has elapsed, the writer should thoroughly check his report in regard to organization, content, form, and style. If possible he should have someone else look the report over in an effort to see whether it is clear and achieves its intended purpose. Then placing himself in the place of the reader, he should determine whether or not the subject is clear from the beginning. He should make certain that the report is logical and clear. Each statement must look both backward and forward; each must be a bridge over which the reader can easily pass in his efforts to understand the report. The data must be interpreted for the reader, for, contrary to the popular saying, *facts do not speak for themselves,* and the efficient report writer interprets them so that his reader cannot misunderstand. Most important of all, however, he should determine whether or not the report will leave the reader with the desired point of view, i.e., whether or not *it does what it was meant to do.*

The report should be checked to see if all parts are clearly identified and all are easily accessible. The form, supplementing and supporting the organization of the report, should make all titles clear by consistent use of headings, capitalization, location, and spacing. Coordinate sections should have identical format, and subordination should be made obvious by correct use of form. Some attention should be given the need for organizational devices such as a table of contents, an index, and an abstract.

In matters of style, the writer should check his report carefully to make certain that all "deadwood" is removed, making his report as direct and as concise as full understanding will allow. Last, he should check the report for mechanical errors in spelling, punctuation, and grammatical construction.

Preparing the Final Copy

In preparing the final copy of his report, the writer should use standard materials and insist on a

(Continued on page 28)

STRAIGHTENING STRUCTURAL MEMBERS IN PLACE*

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Introduction

Through the years, techniques have been developed for the straightening of bent members by the judicious application of heat, hammer blows, or transverse force, singly or in combination. Joseph Holt, of Seattle, has been a pioneer in the development and application of these techniques. His success in straightening damaged highway-bridge members led the Engineering Experiment Station of the University of Washington to sponsor a research project to study his methods, the underlying principles, and the effects on the metal in the members being straightened. The project was undertaken by the author, as a research fellow in the Experiment Station, with the cooperation of Mr. Holt.

This article is based upon the author's own experiments, and upon his observations of Mr. Holt's methods, supplemented by discussions with Mr. Holt. The author assumes full responsibility for all statements and opinions expressed herein.

Straightening Techniques

The heat-straightening method is based essentially upon restrained thermal expansion along an edge that needs to be shortened. Expansion, yielding and upsetting are caused by suitably localized heat application, after which the actual straightening is accomplished by the contraction that occurs during cooling.[1,2]

When a structural member is bent, one edge of that member becomes longer than the other. If the two edges can again be made the same length, the straightening is accomplished. A member may be straightened by shortening the longer edge, by lengthening the shorter edge, or by a combination of both. Straightening by heating attacks the problem by shortening the longer edge. However, it is entirely possible to lengthen the shorter edge; this additional method of attack will be discussed also.

As mentioned previously, restrained thermal expansion of the metal causes an upsetting action. This action shortens the member in the heated area and upon cooling, contraction "pulls" the member back into line. Mr. Holt has summarized the method as follows: "The method of applying the heat must be such that the steel instead of expanding in length will upset, or expand into itself, so to speak. Also to make this method work there must be portions of the member cold enough, strong enough, and so situated as to force the metal to upset, or expand into itself, when and where heated unless some outside force can be added." In general, heat must be applied in such a manner that the member itself can furnish sufficient restraint to cause upsetting.

To illustrate the use of heat for straightening bent members, the straightening of an unrestrained member of simple cross section will be discussed. A bent piece of flat bar is shown in Fig. 1. To straighten this member, an oxyacetylene torch is first applied at point B; heating at this point causes expansion in the immediate area. This expansion cannot cause much elongation of the bar because most of the bar is cold and resists such elongation. Thus the heated metal around point B upsets, once the yield point has been exceeded. At the temperatures (up to 1200° F) used in straightening, the yield point of the metal in the heated area is considerably less than that of the cold bar. Having point B heated, the torch is used to heat the shaded area, working slowly from point B to the edge of the bar. As the torch moves toward the edge, upsetting occurs in the immediate area of heating. After cooling, the bar will have moved toward the straightened position shown by the dashed lines, the contraction being in the direction shown by the arrows. Further "heats" (heating-and-cooling cycles) will complete the straightening.

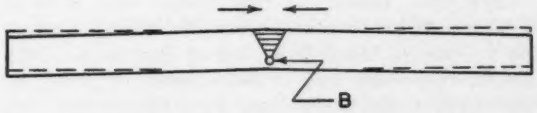

FIG. 1. BENT FLAT BAR

* Abridged by Blake D. Mills, Jr., from the article of the same title in the *Welding Journal Research Supplement*, May, 1952, and reproduced by permission of that journal. The work was originally reported in the author's thesis for the degree of M.S. in M.E., 1951.

The purpose of the V-shaped heating area is to increase the upset proportionately from point B to the edge of the bar; point B acts somewhat like a hinge. According to Mr. Holt, by properly heating a V, most of the residual stresses caused by heating are relieved. Observations made by the author tend to verify this statement.

The use of a transverse force can frequently be of value when straightening with heat. By producing compression in that portion of the member which is to be heated, upsetting is facilitated. At the limit, all the thermal expansion goes into upset, if the external force stresses the steel to its yield point. Of course, the greater the upset per heat, the fewer are the heats required to accomplish straightening.

Mr. Holt introduced the author to the principle that steel under tension tends to yield to relieve that tension, if subjected to light hammer-peening in the tension area.[3] The principle is useful in straightening, being a means by which the shorter edge of a member can be lengthened. With the transverse force acting to provide compression along the longer edge of a bent member, the shorter edge, in tension, may be peened to speed the straightening.

The peening is done with the flat surface of a hammer, backed by a second hammer or sledge. Light blows are used; to casual observation, the peened surface is not marred. The fact should be noted that the yielding of the steel appears only slightly due to the thinning action of the hammer blows.

If a member, in being bent, has upset in compression, the only way to straighten the member is to hammer out the thickened section, unless a permanently shortened member is acceptable. This type of peening will be sufficiently violent to work-harden the steel in the area involved, resulting in less desirable mechanical properties. However, if such an area is sufficiently heated afterward, one would expect the effects of work-hardening to be reduced.

An illustration of the basic straightening techniques in straightening a bent bridge member is now in order. In 1949 the wooden decking burned on the Snake River Bridge near Pasco, Washington. As a result of the heat, many members of the bridge became severely warped. The Highway Department of the State of Washington engaged Mr. Holt to straighten 70 floor beams and two struts. With these members straight and with added support from below, the bridge could be made to handle one-way traffic until a new bridge was completed.

The floor beams for this bridge were built-up I-beams 28 in. deep and about 20 ft long. Though an average of about 6 in. out of line, most of the beams responded well to heat alone, requiring no additional methods of attack for straightening. Not so for one of the struts.

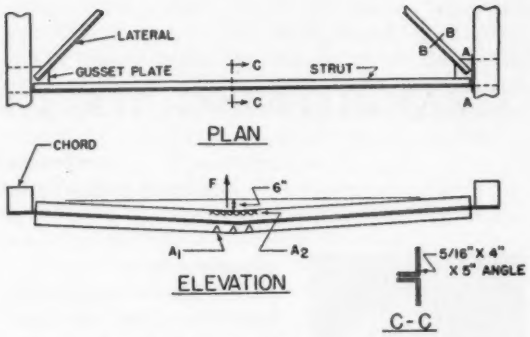

FIG. 2. SNAKE RIVER BRIDGE STRUT

This member is shown in Fig. 2. Built up of two 5/16- x 4- x 5-in. angles with the 4-in. legs together, the member was 6 in. out of line. The straightening of this member was made difficult because the gusset plates were bent considerably, and attached to them were laterals, all of which resisted the raising of the strut. Heat alone would not move the member; other means had to be employed.

First, a chain hoist was used to place a force on the member as shown by the arrow on the sketch. With this force in place, the area in which heats were to be made was subjected to compression; upsetting was enhanced. Heat was applied to areas similar to A_1 to cause a shortening of the longer edge of the strut.

Taking advantage of the area subjected to tension, light peening was applied to area A_2, speeding the straightening. Care was taken in applying heat and peening so that the straightened member would have its original length.

Because restraint existed at the ends of the strut, a second chain hoist was employed. This hoist was used as an aid in raising the bent gusset plates. One gusset plate was lifted at a time. With the lifting force in place, heat was applied along lines A-A and B-B. The reduction in yield point of the steel allowed a re-positioning of the strut ends.

Though discussed separately, the straightening of the strut and the lifting of the gusset plates were carried out simultaneously to produce the final result, a straightened member of unimpaired length.

Experiments with Members Under Load

Of particular interest are the techniques to be used in straightening members which are parts of structures, and therefore carry loads. The most difficult straightening situation occurs when the bent member is loaded axially in compression. This condition can produce tension in the area in which heats are to be made. Upsetting is at a minimum because a part of the expansion goes to satisfy the tension. The usual V-pattern of heating is ineffective in areas

of high tensile stress. Laboratory experiments were conducted on members under load, to determine more effective heating patterns to use when working with tension areas. Of course, one means of combating tension areas is to make use of an external force.

A simple frame was arranged, such that a bent member could be loaded in axial compression by the tightening of two turnbuckles. The bending moment, produced by the axial load and the eccentricity due to the bend, creates (as well as a compression area) a tension area which must be heated in order to straighten the member. Using this simple arrangement, various heating patterns were studied.

Angles were used for the experiments because, due to the geometry of the cross section, they present more difficulties in straightening than do some of the other structural shapes.

A typical experiment proceeded as follows: A 40-in. length of ⅛ x 1½ x 1½-in. angle was bent about 1 in. out of line using a hydraulic press. As much as possible, the bend was kept in the plane of one of the legs. The angle was then bolted to the frame and loaded in compression until out of line by an additional ⅛ in. Under these conditions, the maximum tensile stress produced was estimated to be in excess of 20,000 psi. A dial gage was mounted in such a manner as to indicate the amount of straightening. With the setup complete, any heating pattern could be applied; its effectiveness was manifested by the change in readings of the dial gage.

Though many heating patterns were tried, three are typical of all. First, V-heats were used in the usual manner. Second, in the vicinity of the bend, the edge was heated; when cool, a second strip was heated, this time further in toward the heel of the angle. Third, the V-pattern was followed, but the heating was discontinued after about four-fifths of the way out along the V. The remaining portion of the V was heated separately after the first portion had cooled.

The usual V-pattern heats were not highly effective in producing straightening, as should be expected. However, these heats seem to be able to relieve the residual stresses produced by the other heating patterns when improperly used.

In general, the greatest amount of straightening for a single heat can be accomplished by heating a portion of the longer edge of the member. By confining the heat to one edge, the remainder of the member is kept sufficiently cold to provide maximum restraint for upsetting. However, a high-tensile stress is left along the edge, and as a result, a second edge-heat will accomplish little or nothing, the expansion going to relieve the tension. The high-tensile stress must be relieved. A zone of compressive stress must balance the tensile stress; a heat in this zone causes upsetting which tends to relieve the edge tension. Thus the second heat is applied along a strip further in toward the heel of the angle. In practice, the author has never been able to relieve fully the tension produced by the first edge-heat, and after several cyces of heating, the process failed to produce further straightening. However, the use of the usual V-heats allows sufficient plastic flow to equalize the residual stresses, and thus to restore the effectiveness of the edge-heat pattern.

The edge-heat pattern can be extremely dangerous when used to straighten a member under axial compression; this fact cannot be emphasized too strongly. The edge to be heated is the portion of the member carrying the highest tensile stress. A softening of this edge by heating may well reduce the load-carrying capacity of the member to the point of further deflection and failure. In the experiments, an effective edge-heat has reduced the deflection of the angle by almost $\frac{1}{10}$ in.; however, in one case where the axial load was high, an edge-heat caused the deflection to increase by ¼ in. A similar situation occurring in a structure might well spell disaster.

The interrupted V-heating pattern seems to be the best technique for members under axial compression, from both the standpoints of effectiveness and consistency of results. In this system, the initially unheated portion of the V tends to go into compression because of the upset and contraction occurring in the heated portion. This tendency toward compression relieves the tension produced by the bending moment. When the outer portion of the V is heated, upsetting is favored in two ways. First, as just mentioned, the tendency toward compression exists here; and second, the heating is along the edge, a feature which is conducive to obtaining maximum restraint by keeping most of the member comparatively cold.

It should be noted that, as the member straightens, the eccentricity is reduced, resulting in a smaller bending moment and smaller stresses imposed by bending. Thus, the usual V-heat is capable of finishing the straightening job once it is well under way.

About 265 separate heating-and-cooling cycles were employed during the period of experimentation. The temperatures reached during heating did not exceed 1400° F; even at this temperature, the areas heated had a tendency to buckle slightly and form ripples.

Testing Program

No one who has had occasion to see the results of Mr. Holt's work with structural members can doubt the potency of the straightening method. However, at times, the question has arisen concerning possible damage to the steel. A limited program of tests was

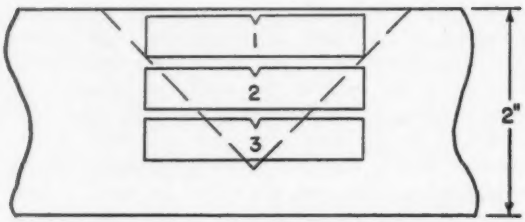

FIG. 3. IMPACT TEST SPECIMEN POSITIONS

run in an attempt to gain some indication of the change in mechanical properties brought about by the straightening process. The program included tension tests, hardness tests, impact tests, and the taking of photomicrographs. The material used was a 20-ft section of ¼-in. x 2-in. mild steel, cut into bars 20 in. long.

Seven of these bars were bent edgewise until ¼-in. out of line with the load removed, and were then heat-straightened. Four bars were retained as standards for comparison.

Tension tests of the bars, unmachined, showed that heat-straightening had no significant effect on tensile strength or yield strength, and it only slightly reduced the percent elongation in 8-in. gage lengths. No fractures occurred within the heated zones of the straightened bars.

In the heated zones of the bars, the heat-straightening operation increased the average Rockwell B hardness by about two points, from 83 to 85. Notched-bar impact specimens were machined from the heated zones as shown in Fig. 3, and from the corresponding positions on the standard bars. Impact tests, conducted at 65° F, 35° F, and 0° F, showed no loss of notch toughness attributable to the heat-straightening.

For photomicrographs, specimens were machined from the heated zones and from the standard bars. No difference in microstructure was observed.

It may be well to note that in the heat-straightening of these test bars, care was taken to keep the temperature of the steel below 1300° F, using Tempilstiks for temperature determination. Excessive temperatures could have detrimental effects on the properties of steel members.

Fatigue tests might well serve as an indication as to whether or not damage is done to the surface of the steel by the high-temperature flame; some burning may take place during the heating. The American Railway Engineering Association's Bulletin No. 460 discusses the flame-shortening of eyebars to equalize the stress. In shortening an eyebar, a 12-in. length is heated to a temperature between 1600° F and 1800° F, using an oxyacetylene torch. Then, the required upset is obtained by the use of a special clamp. After a series of tests, the conclusion reached was that flame-shortening has no appreciable effect on either fatigue or static strength.

Because of the limited nature of the testing program, no positive statements can be made regarding the effect of straightening with heat on the mechanical properties of mild steel. However, the consistency of test results appears to indicate that no significant changes occur in the steel.

Conclusion

The author has outlined some basic principles and current techniques involved in the straightening of structural members in place, and has described some relevant experiments which he personally conducted. The information presented is only fragmentary coverage of the subject, whose importance is perhaps best indicated by the marked success of Joseph Holt and others in the restoration of damaged steel bridges. The current techniques of straightening are highly effective when applied by an expert. However, inexpert attempts toward straightening a bent structural member under load could well be disastrous to the structure, as the result of unexpected deflections caused by heat application. Further research is desirable, toward a better and more widespread understanding of the behavior of metal members during straightening. Such research should be amply justified by its eventual contribution to the field of structural engineering.

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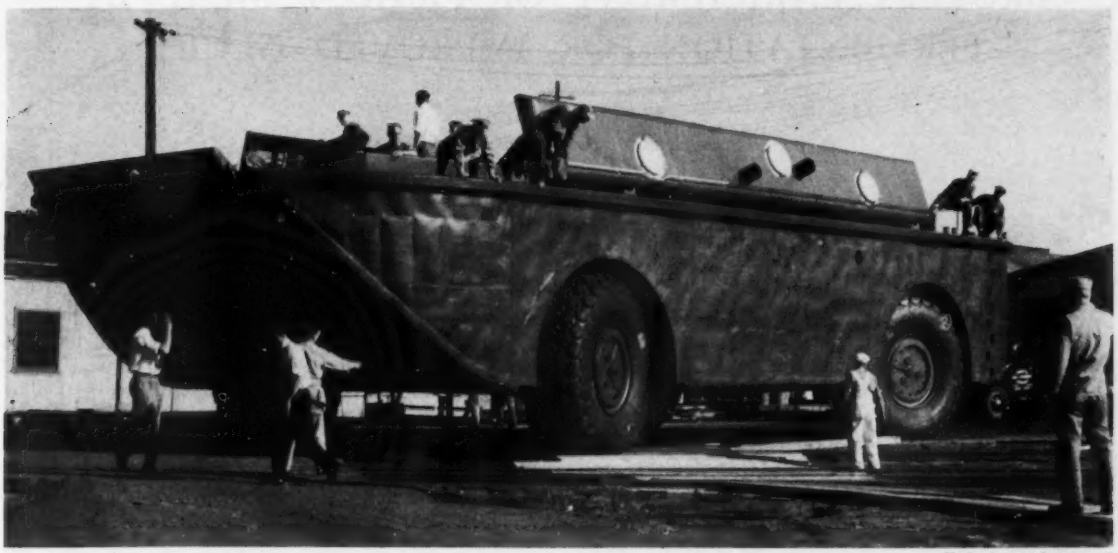
"The true effect of an invention is always that a given amount of manual labour and of nervous energy, and of brain-capacity, will produce a greater amount of the material goods which mankind requires. Thus the progress of invention should mean the greater productivity of labour. Furthermore, it is the high-grade labour, which will increase its productivity in the greatest ratio. . . . But high-grade labour requires high-grade management. You cannot make a greater mistake than to think that as the status of labour rises, the need for management declines. The higher the status of the workman, the more precious he becomes, and the less can any waste of his time or ineffective use of his work be tolerated."

—A. N. Whitehead, "Education and Self-Education,"
from *Essays in Science and Philosophy*, New York, Philosophical Library, Inc., 1948.

"BARC" Tests Will Be Run In Structural Lab



U. S. Army photograph

THE PROTOTYPE of a new 60-ton amphibious type cargo carrier known as the "BARC" has been constructed for the U. S. Army Transportation Corps by the Pacific Car and Foundry Company and is presently undergoing engineering and performance tests in the Seattle area before being formally delivered to the Army. The experimental vehicle—somewhat similar on a magnified scale to the famous "Dukw" of World War II—is designed for over-the-beach transportation of heavy equipment such as tanks, trucks, small rail locomotives, etc., as well as artillery and other large pieces of military equipment.

The "BARC" will be officially unveiled sometime next month at a formal ceremony and demonstration at Fort Lawton to be attended by high government and Department of Defense officials. At this time structural, mechanical, and performance details cannot be disclosed, Army officials said.

Under contract with the U. S. Army, the Structural Research staff are conducting tests in the 2,400,000-lb. machine. The Electronic Group is also taking part in a series of field tests.

SUSPENSION-BRIDGE RESEARCH DRAWS DIRECTOR TO EUROPE

F. Burt Farquharson, Director of the Engineering Experiment Station and Professor of Civil Engineering, recently spent six weeks in Europe, during which he attended the Cambridge, England, meeting of the International Association for Bridge and Structural Engineering August 24-29, inspected British and Continental suspension bridges and bridge sites, and conferred with leading bridge and structural engineers.

Professor Farquharson's paper on "Model Verification of the Classical Flutter Theory as Adapted to Suspension Bridges," which appeared in Vol. 12 of Publications of the IABSE, grew out of special tests on thin flat-plate models in 1948-49, after tests on the new Tacoma Bridge models revealed that flutter played an important part in the behavior of the models under wind action.

Bridge sites in Scotland and Wales, notably the Menai Straits Bridge in Wales, and new bridge construction in Oslo, Norway, were on his itinerary. At Trondheim, Norway, he was invited by Professor A. Anderson, of the Technical University of Norway, to give a lecture on suspension bridges. In Norway, he also renewed acquaintance with Dr. L. Conradi, former research fellow in the E.E.S. and now Chief of the Inorganic and Metallurgical Section of the Norwegian Defense Research Establishment.

In Zürich, Switzerland, Professor Farquharson visited Dr. J. Ackeret of the Swiss Federal Institute of Technology. Returning to England, he visited the site of the proposed Severn Bridge and later inspected the site of a proposed suspension bridge over the Firth of Forth in Scotland. He had several conferences with the engineering firms of Mott, Hay, and Anderson, and Freeman, Fox, and Partners, designers of these two bridges, as well as with Dr. R. A. Frazer of the National Physical Laboratory

(Continued on page 23)

PROTEIN ENRICHMENT OF PEANUT MEAL BY FERMENTATION FOR IMPROVED GLUE*

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P. K. B. Chaudhuri

During World War I the need for water-resistant glue for the construction of military aircraft, then made chiefly of plywood, aroused interest in casein glue and promptly led to a thriving industry in its manufacture. The casein was subsequently replaced by soybean meal, particularly in the softwood plywood industry of the Pacific Coast. Although the current trend in the plywood industry has been the replacement of soybean and other protein glues by synthetic resins, protein glues still predominate, and the consensus of the plywood experts is that the synthetic resins "will not achieve their objective within the next ten years."[1]

The achievement with soybean meal suggested that other seedmeals, namely, meals of cottonseed, peanut, linseed, etc., might find their use in making plywood glue, but the results obtained with them by the early workers were inferior to soybean meal. In the case of peanut meal, it was contended that the lower water-resistance of the glue was due to its high carbohydrate content, about 20 to 25 per cent. Carbohydrates cut down the amount of irreversible proteinous gel that could be formed from peanut meal to produce a glue of high water-resistance and strength. Therefore, to ensure improved performance of peanut-meal glue, the protein content of the average peanut meal must be enriched by further treatment. A convenient method of protein-enrichment can be considered in fermentation of the carbohydrate content of the meals with amylolytic enzymes so that their removal by enzymatic degradation will furnish a meal high in protein content. Such a method seems to offer attractive possibilities in a country like India where peanut meal is a surplus commodity and is consumed mainly as feed for animals, so that if peanut meal can be successfully used in replacing the high-priced, imported casein in making plywood glue, the economy of the country will be definitely strengthened. Further, in a country like India where the plywood industry is still in the process of development, and where cold-pressed, water-resistant plywood is still in demand, there is large scope for the utilization of peanut-meal glues, provided such glues have satisfactory strength and water-resistance.

Fermentation of Peanut Meal

Peanut meal can be obtained in two general ways, namely, (1) by pressing out the oil from the kernels in a hydraulic or screw press and (2) by extracting the oil with suitable solvents. Practically all commercially available peanut meals are hydraulic pressed. Because of high cooking temperature, inferior grades of nuts used, non-removal of skin from the kernels, etc., the meal produced by mechanical pressing is of low grade in reference to purity and as a human food, but high in preference to its protein content as a stock feed. Solvent extraction of oil has been reported to produce meal having superior properties due to less denaturization of proteins as compared to mechanically pressed meals[2,3] but it is yet to be adopted by the commercial peanut-oil manufacturers.

In the fermentation study, two peanut meals, one solvent-extracted and the other hydraulic pressed, were selected. The meals were finely ground in a ball mill. In the case of hydraulic pressed meal, the removal of its residual lipid content was found necessary to ensure better accessibility of starch granules to the enzymes.

The various amylolytic enzyme preparations used in fermentation of peanut meals included analytical preparations of alpha- and beta-amylases, diastase malt (U.S.P.), mylase-P, and barley diastase. Mylase-P is a concentrated preparation of fungal enzymes which, besides alpha-amylase and pyrophosphatase, contains other enzymes.

Barley diastase was prepared in the laboratory by following the conventional methods[4] with slight modification: 100 g of freshly ground barley* were

* A concised report of the author's dissertation for the Doctorate submitted to the faculty of the College of Forestry, 1952.

* Barley grains were obtained from Sick's Seattle Brewing & Malting Co., and designated as Eastern Malt of high diastase activity.

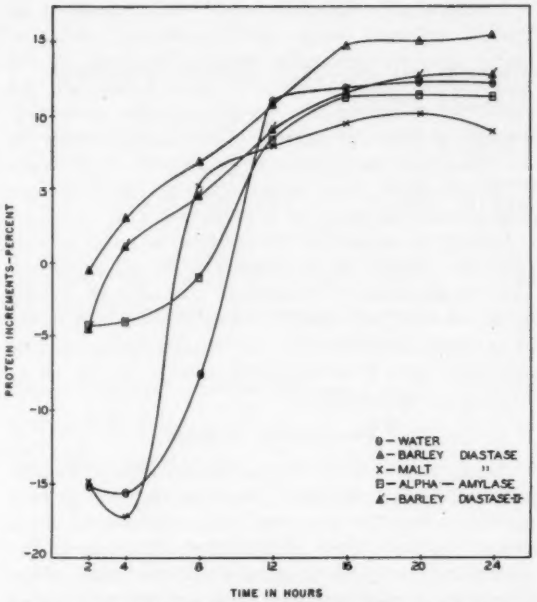

FIG. 1. COMPARATIVE EFFECTIVENESS OF DIFFERENT ENZYMATIC PREPARATIONS IN ENRICHING PROTEIN CONTENT OF SOLVENT EXTRACTED PEANUT MEAL

digested with 250 ml of water and then centrifuged. To each 10 ml of the centrifuged liquor was added double its volume of 95 per cent ethyl alcohol to precipitate the enzyme mixture, which then was quickly centrifuged. The wet precipitate was suspended in water to make it ready for use. As the diastase tends to form clumps, shaking vigorously with water produced a suspension of smooth consistency.

In a set of preliminary experiments the amounts of amylase preparations required for a satisfactory degree of protein enrichment were ascertained. In the fermentation experiments, suspensions of 5-g meal-fractions in water were treated with different enzyme preparations and were allowed to ferment, generally at 50° C, for different periods of time. After the desired period of fermentation, the meals were centrifuged for ten minutes at 4,100 rpm in a Serval Angle Centrifuge. The settled meals were dried at 50° to 60° C for 24 hours. The protein contents in fermented meals and in the centrifuged, supernatant liquor were determined by the Gunning Method.[5] Along with fermentation, the meals were digested with water alone, and the protein-enrichment in water-digested or autolyzed meals was compared with that of the fermented meals to evaluate the effectiveness of fermentation of meals.

The percentages of protein increments in fermented meals, as plotted in Figs. 1 and 2, show that during the earlier periods of fermentation a fraction

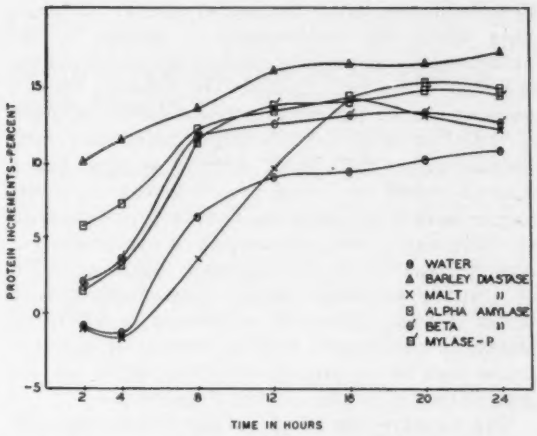

FIG. 2. COMPARATIVE EFFECTIVENESS OF DIFFERENT ENZYMATIC PREPARATIONS IN ENRICHING PROTEIN CONTENT OF HYDRAULIC PRESSED PEANUT MEAL

of protein is peptized and lost in the supernatant liquid, thereby producing lower protein increments or at times a protein decrease in the fermented meals. The amount of protein lost depends upon the peptizability of protein in the original meal. Thus in the case of solvent-extracted meal of 75 per cent peptizable protein, the protein-loss during the earlier periods of fermentation is much higher than that of the hydraulic pressed meal of 58 per cent peptizable protein. The peptizability of protein in peanut meals is measured by its solubility in a molar solution of sodium chloride.[3]

The fermentation of peanut meals with different amylase preparations shows that generally during 16 hours of fermentation at 50° C, sufficient protein enrichment can be attained which remains stable for a succeeding period of 16 to 24 hours. Of all the enzyme preparations so far studied, freshly precipitated barley diastase is found most effective in protein enrichment, inasmuch as 15 to 17 per cent of protein enrichment is obtained. Digestion of peanut meals with water alone brings about 10 to 12 per cent protein enrichment, thus signifying the superiority of fermentation of meals in attaining a higher degree of protein enrichment. During fermentation, carbohydrates are gradually hydrolyzed by the enzymes and removed in the centrifuged filtrate, thereby producing a meal richer in protein content. During water-digestion of meals, only the easily soluble fraction of carbohydrates is leached out, so that retention of a large amount of carbohydrates is revealed in lower degree of protein enrichment.

Determination of the protein content in the supernatant liquids from the centrifuged, fermented meals shows a high initial loss of protein during 2 to 8 hours of fermentation, followed by a sharp drop

in protein-loss during the period of 8 to 12 hours, after which the concentration of protein in fermented meals remains comparatively stable during the rest of the fermentation. The different enzyme preparations are found to exercise a specific influence on the loss of protein during fermentation. Malt diastase causes the highest protein-loss while barley diastase shows the lowest protein-loss. It is, therefore, evident that protein enrichment in peanut meals by fermentation is a combination of two processes,[6] namely, removal of carbohydrates and coagulation of a part of peptizable protein. The effectiveness of barley diastase in protein enrichment is due to its ability to break down a large amount of carbohydrates and to its greater inhibiting action on the peptizability of protein during fermentation.

The measurement of pH of the fermenting meal suspensions indicates that during fermentation there is a gradual drift in pH from the range of 6.6 to 6.4 during a 2-hour period to the range of 4.4 to 4.2 during a 24-hour period. The drift in pH during fermentation appears to be due to the meal itself rather than to the added enzymes, as both enzymes and water were found to produce the same trend in pH change. The gradual increase in the acidity of the fermenting medium has a beneficial effect in more than one way. First, the acidity of the fermenting medium of the fermenting medium at certain stages corresponds to the pH recommended for the optimum activity of enzyme preparations. Second, the drop in pH being towards isoelectric range of peanut protein, namely pH 4 to 5, much of the protein peptized during the initial part of fermentation is coagulated, as observed in the determination of protein loss in the supernatant liquids from fermented meals. Further, as the same pH drift was observed when standard buffers were added to the meal suspensions and as no appreciable improvement in protein enrichment was attained, the use of buffers during fermentation can be eliminated.

The effectiveness of fermentation in protein enrichment of peanut meal is further confirmed (1) by indirect calculation of the amount of non-proteinous material removed during fermentation, (2) by determination of reducible sugar formed during fermentation, and (3) by the study of photomicrographs* of fermented and nonfermented meals. During fermentation, higher amounts of carbohydrates are hydrolyzed so that the value for reducing sugars formed is approximately 4 to 5 times greater than that found during the water-digestion of meals. The photomicrographs of fermented meals show the presence of fewer starch granules than are present in original or water-digested meals.

*A report of this part of the study will be published in the near future.

Amounts of recoverable meal were found to be low in the early stages of fermentation owing to higher loss of peptizable protein fractions in the supernatant liquid. As the reaction proceeded, the amounts of recoverable meal gradually increased, depending upon the degree of protein enrichment in the fermented meal. Generally, after 16 to 24 hours of fermentation with barley diastase, 65 to 70 per cent of the original meal is recoverable.

During fermentation the protein in meal is considerably denatured, as measured by its solubility. The denaturation of protein is caused both by the action of heat and acidity. Denaturation was found to increase progressively during 16 hours of fermentation and then remained steady during 16 to 24 hours of fermentation.

Preparation of Glue

After the attainment of protein-enrichment in peanut meals by fermentation, the next step was to prepare glues from the fermented and unfermented meals and to evaluate their performance by judging the strength and water-resistance of the glue-joints. Strengths of glues prepared from a sample of isolated peanut protein were also studied to judge the importance of protein enrichment on the performance of peanut-meal glues. The formulations used for peanut-meal glues are of the same type as those followed with soybean meal and casein, as they are all proteinous in nature. The components and proportionate quantities used in glue formulations were as follows:

Meal	100 grams
Hydrated lime	15 "
Sodium hydroxide	4 to 10 "
Silicate of soda (41° Baumé; $SiO_2 : Na_2O$: : 28.7 : 8.9)	30 "
Mix. of carbon disulphide and carbon tetrachloride (75/25)	2 ml
Total water	350 to 470 ml

The addition of components followed the same order as in any commercial soybean-glue formulation. After the addition of the last ingredient, the glue was stirred continuously by a motor-driven stirrer for 30 minutes, when it was considered to be of suitable consistency for application. The following gluing schedule was adopted:

Glue spread	80 lb per 1000 sq ft (S.G.L.)
Closed assembly period	5 to 15 minutes
Pressure	200 psi, overnight at room temperature
Age of glue when used	35 minutes to 1 hour
Size of plywood panel	7 in. by 7 in.
Thickness of veneer	1/8 inch
Species of wood	yellow birch, *Betula lutea*

TABLE I

Comparison of Dry Strength and Water-Resistance Glues Prepared from Peanut Meals of Varying Degrees of Protein Enrichment

Type of Meal	Protein %	Peptizable Protein %	Plywood Shear Tests			
			Dry		Wet	
			Strength %	Wood Failure %	Strength psi	Wood Failure %
Hydraulic Pressed Meal	48.4	54.8	240	20	125	0
Fermented Hydraulic Pressed Meal	66.4	8.7	300	60	180	15
Solvent-Extracted Meal	50.8	74.8	275	5	139	0
Fermented Solvent-Extracted Meal	63.1	16.5	375	45	165	0
Isolated Peanut Protein	96.9	16.3	440	45	205	0
Commercial Soybean Meal	....	....	240	20	120	5

The dry and wet (after 48 hours soaking in cold water) shear strengths of glues prepared from meal of varying degrees of protein enrichment are shown in Table I.

These dry and wet shear strengths indicate that the enrichment of the protein content of meals to the extent of 14 to 18 per cent as carried out by fermentation assures higher strength and water-resistance for peanut-meal glues. It has been contended that the high degree of denaturation of protein in peanut meal might cause lower strength values in peanut-meal glues.[6] It is true that during fermentation considerable denaturation of the protein occurs, yet the fermented meals are found to form glues of higher strength and water-resistance. From the results in Table I, it can be concluded that, in the case of peanut meals, the customary method of measuring the denaturation of protein by its solubility in a molar solution of sodium chloride does not reveal true denaturation insofar as its performance as glue is concerned. It is also probable that denaturation of the protein in meals during fermentation is more than counterbalanced by the enrichment of protein content. Thus protein enrichment definitely improves the quality of peanut-meal glues. The working life of more than 3 hours, closed assembly period of more than 15 minutes, and the working schedule of protein-enriched peanut-meal glues show that such glues can be advantageously adopted in commercial operation.

Acknowledgment

The author wishes to express his gratitude to Dr. Bror L. Grondal, Professor of Forest Products, under whose supervision this work was carried out.

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SUSPENSION-BRIDGE RESEARCH DRAWS DIRECTOR TO EUROPE

(Continued from page 19)

at Teddington. During his last trip to England in 1946, Professor Farquharson had attended technical meetings in connection with the design of the Severn Bridge, which will have a suspension span of 3,300 feet. (The suspension span of the Tacoma Narrows Bridge is 2,800 feet.)

George S. Vincent, Principal Bridge Engineer of the U.S. Bureau of Public Roads, who has been associated with Professor Farquharson in the suspension-bridge tests for the past seven years, though unable to attend the Cambridge meeting, was author of a paper which also appeared in Vol. 12 of the IABSE publications. It was entitled "Mathematical Prediction of Suspension-Bridge Behavior in Wind from Dynamic Section-Model Tests."

Height of Large Testing Machine to Be Increased

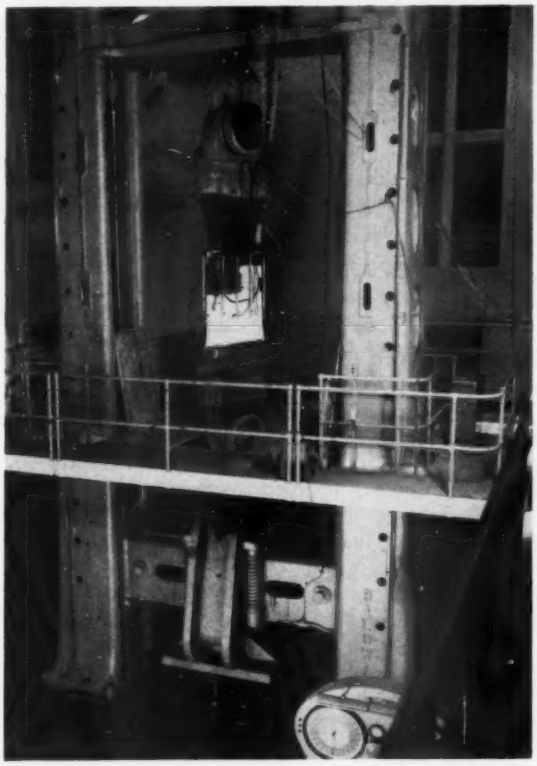
ALTHOUGH THE 2,400,000-LB TESTING MACHINE in the Structural Research Laboratory represented the most advanced type of its kind when it was installed in 1946, experience since then has demonstrated its lack of capacity to handle long tension specimens. This fact became finally apparent during a series of tests for the Bureau of Ships on "Reinforcement Around Openings in Ships' Plating," which are still under way.

Careful study of the whole problem showed that raising the height of the machine by eight feet would be a comparatively simple matter of designing a pair of welded pieces to duplicate the upper section of the present cast-steel columns. The operating schedule will not be seriously disturbed during the alteration.

The difficulty of limited tension specimens is due to the installation of clevises instead of air-operated grips. Early judgment that clevises would be the more useful has been borne out, but the present serious specimen limitation makes a larger capacity imperative.

A contract was let September 3 to the Valle-Sommers Company, calling for the cutting of an opening in the roof immediately over the testing machine and the erection of a penthouse which will provide operating and hoisting space. The column extensions will then be fabricated in a local plant and an additional contract will be negotiated for their erection. This process, though somewhat "tricky," will be simplified by the fact that the present machine has a 50-ton hoisting capacity.

These operations will make full use of some 20 tons of steel on hand, thus allowing the remainder of the Bureau of Ships work to be completed.



STRUCTURAL TESTING MACHINE WITH SPECIMEN 3' x 7' BETWEEN PULLING HEADS

STUDY TO PREDICT WATER STORAGE IN COLUMBIA BASIN

A TWO-YEAR CONTRACT has been negotiated between the Bonneville Power Administration and the University for an investigation leading to long-range streamflow forecasting in the Columbia River Basin as required for power. The study will be made cooperatively by the Department of Civil Engineering and the Department of Climatology and Meteorology. T. H. Campbell, Associate Professor of Civil Engineering, will be the supervisor.

With additional storage reservoirs and power-generation facilities now being added on the Columbia River and its major tributaries, the problem of accurate and continuous evaluation of the river's power potential has assumed increased importance. A detailed and continuous study of the climatological and hydrological aspects of the problem is being undertaken.

Those phases involving temperature effects, particularly snow-melt investigations, will be allocated to the Department of Meteorology and Climatology under supervision of Dr. Phil E. Church, head of the department. Such studies as distribution of rainfall and runoff, correlation of data with seasons, temperatures, etc., and statistical studies to determine the applicability of theories of pattern and persistence to flow forecasting, will be made by the Department of Civil Engineering.

Students, chiefly graduates, will be assigned by both departments to those problems which they are qualified to handle.

Motor Courses Designed for Greater Safety and Efficiency

DURING THE PAST DECADE, various training courses for teachers of driving, truck owners, motor vehicle fleet supervisors, and maintenance foremen have been held periodically on the campus, sponsored by the University of Washington together with other cooperating agencies. Professor Fred H. Rhodes, Jr., of the Department of Civil Engineering, has been the general director of these courses. Past courses or "schools" have included the following:

The Annual Training Course for Motor Vehicle Fleet Supervisors was given each year, 1944-51. In March, 1952, a two-day refresher course was offered, covering "How to Choose and Train Good Drivers," "How to Interview Applicants for Jobs," "Human Relations in the Motor Fleet Industry," etc. Professor A. E. Neyhart, Administrative Head, Institute of Public Safety, Pennsylvania State College, who is also Consultant on Road Training of the A.A.A., has been special instructor of these sessions.

Driver Education and Training, "A Short Intensive Basic Course for High School Teachers," started in 1941, was offered each year 1946-51, also with instruction under the direction of Professor Neyhart. During August 25-29, 1952, an Advanced Workshop was offered to teachers who had completed a basic course. Programs included lectures and discussions as well as practice-driving demonstrations. About 20 driving teachers, from high schools and commercial driving schools, were in attendance.

In March, 1951, a Top Management Conference for Executives and Owners of Motor Fleets was sponsored by the University in cooperation with Oregon State College and the University of British Columbia. This course rotates among the sponsoring institutions; in 1953 it will be offered at Corvallis.

Last June 5-7, the First Annual Preventive Maintenance and Failure Analysis Conference was held on the campus, with Lee Ketchum of Seaboard Motors, as Assistant Conference Director and Michael Guidon, Assistant Professor of Mechanical Engineering, representing the M.E. department on the Promotion Committee. Chief topics of discussion were mechanical operating problems as well as ways and means of developing and improving failures and establishing wear limits. In attendance were some 50 representatives of trucking firms, bus lines, school districts, and manufacturing companies.

During the coming year the Basic Fleet Supervisors Course is scheduled for April 27 to May 1, 1953. Dates for the 1953 Preventive Maintenance meeting have not yet been set. The Driver Education and Training Course, as usual, will be given the last week in August. It should be noted that this is not a course for drivers, but for instructors of driving.

Inquiries regarding any of these courses should be directed to Professor Fred H. Rhodes, Jr., 210 More Hall, University of Washington, Seattle 5.

ELECTRONIC GROUP FUNCTIONS COVER WIDE FIELD

Within the past year, activities of the Electronic Group (Project 28), including A. B. Jacobsen, Instructor in Electrical Engineering, L. D. Barter, Junior Research Engineer, and their staff of assistants, have spread in several new directions. Following the investigation for B. P. A. on the effect of smoke, dust, and wind on radio noise (*The Trend*, October, 1951), and the design of the seismographic data recording instrument described in the last issue, Mr. Jacobsen in June and July undertook a vibration and seismic investigation at the Anchorage, Alaska Hospital at the request of the Boespflug-Knutson-Morrison Company, contractors. A similar study was made in August by Mr. Jacobsen and John W. Jones, Assistant Seismologist of the Geology Department, at the Chief Joseph Dam and its vicinity. In both cases the question of possible damage in the vicinity caused by blasting, was raised. Earth displacement and frequencies were measured.

Arrangements have now been made for the group to act as electronic consultants for a project in the Department of Psychiatry sponsored under a two-year contract with the Army Air Corps. The study concerns psycho-physical tests for prospective Air Corps pilots and is under the joint supervision of Dr. Herbert S. Ripley, Executive Officer of the Department of Psychiatry, and Dr. Albert F. Axe, instructor in the department.

During the past year assistance has also been given on O.N.R. projects, and, at present, work is being done for Operation BARC, described on page 25.

Cost of all these investigations is borne by the sponsoring agencies.

Engineering Research Dividends

Recent theses submitted for advanced degrees from the College of Engineering, University of Washington, will regularly appear in abstract form in *The Trend*. Complete copies of these theses are available for reference at the University of Washington Library. Address inquiries to the Director of the Engineering Experiment Station, University of Washington, Seattle 5.

KUSUDA, T., "Construction of an Over-all Heat Transfer Coefficient Test Apparatus for Building Materials." M.S. in Mechanical Engineering, 1952.

In accordance with the ASTM (designation C 236-49 T) code, hot-, guard-, and cold-boxes were constructed in such way that each box had five well-insulated walls and one open end. The hot-box was located with uniform spacing inside the guard-box and the open ends of both hot- and guard-boxes were flush against the test panel. The test panel was placed in the suspension wall, located between the guard-box and cold-box open ends. In order to maintain a temperature difference between the hot and cold spaces being tested, heating and cooling units and their controls were properly designed and installed. At the same time special precautions were taken to secure uniform and steady air flow on the cold surface of the test panel by means of an air-circulation duct. The test range obtained was —10° F to 120° F; however, for the testing condition, a cold-box temperature of zero and a hot-box temperature of 70° F is generally preferable. The over-all accuracy of the obtained results was 5 per cent, and an actual over-all heat transfer coefficient of the window glass showed highly close correlation with the value determined by the previous experiments.

LEONOFF, C. E., "The Stability of Rubble-Mound Breakwaters Under Wave Action." M.S. in Civil Engineering, 1952.

Rubble-mound breakwaters are widely used on the Pacific Coast of North America for the protection of harbors and waterfront structures from the ravages of storm waves. To date, several semirational and empirical formulas for the design of this type of breakwater have been advanced, but, because of the complexity of the phenomena and the difficulty of obtaining accurate data, none of these can, at present, be used with complete confidence. With recent improvements in the methods of forecasting the characteristics of storm waves, it has become possible to place the design of rubble-mound breakwaters on a more scientific basis. The present work consists of the development of a design formula based on the consideration of the dynamic force caused by the breaking wave tending to move rock down the breakwater slope, and the resistance forces. This was revised by the application of corrective coefficients obtained from tests made on a small-scale hydraulic model into the equation,

$$D=\frac{0.00633\,C_b^3}{(G-1)\,(\tan\phi-\tan\alpha)},$$

in which D is the diameter of a spherical rock in feet, required for stability on a given breakwater side slope; C is the velocity of the design wave at breaking in feet per second; G is the specific gravity of the rock; tan ϕ is the coefficient of friction, rock on rock; and α is the angle made by the breakwater side slope with the horizontal. This equation compares favorably with other published formulas over a considerable range of wave heights and periods. The testing program included three different generated waves and four side slopes. The breakwater model was constructed using a crushed rock with a mean particle diameter of 0.925 inches and a coefficient of friction of 1.171. This size was selected to assure turbulent seepage velocities.

MENKE, E. M. "Studies on the Economic Feasibility of Serving Residential Electric Heating in the Pacific Northwest." M.S. in Electrical Engineering, 1952.

The electric heating studies of the Puget Sound Power and Light Company, the Seattle City Light, the Cowlitz County Public Utility District, and the Portland General Electric Company are presented in this paper. The studies are compared and discussed. The use of customer education is recommended, together with possible use of 12-kv distribution voltage to aid the utility in meeting the challenge of this new residential load. The heat pump load is compared to the load of a central type of electric furnace.

Notes and Comments

ENGINEERS IN THE NEWS

H. E. WESSMAN, Dean of the College of Engineering, attended the ten-day centennial celebration of the ASCE in Chicago as well as the joint meeting of the ASEE and ECPD held in connection with it, September 4 to 6. At the joint meeting he was one of the speakers in a panel discussion of contemporary demands on engineering curricula.

A. L. MILLER, Professor of Civil Engineering, took part in a symposium on blast and earthquake effects on structures held at U.C.L.A., June 27, with a paper on "Earthquake Lessons from the Pacific Northwest."

J. L. McCARTHY, Associate Professor of Chemical Engineering, presided as national chairman of the Division of Cellulose Chemistry during the meeting of the American Chemical Society in September, held at Atlantic City. From there he went to Chicago where he attended the meeting of the AIChE and to Victoria, B.C., September 28, for the Tri-Association Meeting (Pacific Section of TAPPI, Canadian Pulp and Paper Association, and West Coast Pulp and Paper Superintendents).

R. G. HENNES, Professor of Civil Engineering, attended the 50th Anniversary Meeting of the ASTM in New York, June 26, where he read a paper on "Strength of Gravel in Direct Shear." He also read a paper on "Reclassification of Highways" before the Good Roads Association at Yakima, September 19, and spoke on the same subject before the Western Interstate Committee on Highway Problems at San Francisco, September 25.

H. L. HARRISON, former research fellow, whose report on the Holt method of straightening structural members appears in this issue, is now a design engineer with Minneapolis-Honeywell Regulator Company.

T. M. STOUT, Instructor in Electrical Engineering, was on the program of the Pacific General Meeting of the AIEE in Phoenix in August, with two papers, "A Block-Diagram Approach to Network Analysis," and "Analogue Methods for Optimum Servomechanism Design." Also on the program was **A. B. JACOBSEN,** instructor in the same department, with "Radio Influence from Power Transmission Lines—Effects of Wind, Dust, and Smoke," co-authored by **G. S. SMITH,** Professor of Electrical Engineering.

Three E.E.S. research fellows of 1952 are continuing graduate work at other institutions: **Y. YOSHIMI** on a scholarship to Northwestern University, and **A. S. KOBAYASHI** and **T. KUSUDA** as research assistants at Illinois Technical Institute.

The Environmental Laboratory was represented June 3 on the program of the Denver meeting of the Industrial Hygiene Section of the Western Branch of the American Public Health Association. **M. STORLAZZI,** Industrial Hygienist, read a paper on "Seattle's Atmospheric Study," and **L. J. SEALEY,** Medical Consultant, presented "Health Hazards of Agricultural Chemicals."

The $1500 graduate fellowship in ceramic engineering offered by the Gladding McBean Company was awarded this year to recent graduate, **W. M. STERRY.**

G. S. SCHALLER, Professor of Mechanical Engineering, attended the annual meeting of the American Foundrymen's Society at Atlantic City last May, with a paper on "Olivine Applications in the Foundry." On October 25, **W. A. SNYDER,** Assistant Professor in the same department, will speak on "Olivine in the Pacific Northwest Foundry," before the Northwest Foundrymen's Conference at Portland.

R. A. HECHTMAN, Associate Professor of Civil Engineering, took part in the centennial meeting of the ASCE, September 8, with a paper, "Slip Under Static Load of Double-Lap Joints with High-Tensile Steel Bolts," presented before the Structural Division.

NEW REPRINTS

Reprint No. 65. "Klystron Circuits," A. E. Harrison, *Electronics,* March, 1952.

Reprint No. 66. "Basic Amplifier for Electronic Instrumentation," A. B. Jacobsen, *Proc. Soc. Exp. Stress Anal.,* Vol. IX, No. 1, 1951.

Reprint No. 67. "Mineralization as Related to Granitization," G. E. Goodspeed, *Econ. Geol.,* Vol. 47, No. 2, March-April, 1952.

Reprint No. 68. "Straightening Structural Members in Place," H. L. Harrison, *Weld. Jour. Res. Supp.,* May, 1952.

Reprint No. 69. "Welded Reinforcement of Openings in Structural Steel Members," D. Vasarhelyi, R. A. Hechtman, *Weld. Jour. Res. Supp.,* April, 1952.

Note: Library distribution of the Reprint Series has been discontinued.—*Ed.*

NEW RESEARCH PROJECTS

Project No. 136. Molecular Weight Distribution of Cellulose. J. L. McCarthy, Associate Professor of Chemical Engineering, Supervisor; H. Cheung, Research Fellow.

Project No. 137. Mechanism of Delignification of Wood. J. L. McCarthy, Associate Professor of Chemical Engineering, Supervisor; J. Olin, Research Fellow.

Project No. 138. Design and Construction of Stack Sampling Equipment. R. N. Kusian, Acting Director, Environmental Research Laboratory, Supervisor; T. T. Kusuda, Assistant.

Project No. 139. A Study of Reactions at Sand-Metal Interfaces. E. A. Rowe, Associate Professor of Mineral Engineering, Supervisor; R. Torgerson, Research Fellow.

Project No. 140. Mass Transfer Rates in a Moving-Bed Ion-Exchange Column. J. L. McCarthy, Associate Professor of Chemical Engineering, Supervisor; W. W. Koenig, Research Fellow.

Project No. 141. Golden Gate Bridge Studies. F. B. Farquharson, Director of the E.E.S., Supervisor. Sponsored by the Golden Gate Bridge and Highway District.

Project No. 142. Ion-Exchange Resin as a Vapor-Phase Catalyst. L. N. Johanson, Assistant Professor of Chemical Engineering, Supervisor; A. J. Herrman, Research Assistant.

AN ENGINEERING APPROACH TO REPORT WRITING

(Continued from page 14)

neat and accurate copy. On its effectiveness and appearance his reputation will depend.

To sum up, the writer who designs his report for its particular industrial function and communicates it successfully to his readers is applying the engineering approach to report writing. This is the realistic approach, for it is the one which best simulates professional conditions.

Report Writing Check Sheet

Analysis

1. What specifically is requested?
2. What is the purpose of the report? The scope?
3. What industrial action is desired?
4. How will the report be used? By whom?

Investigation

1. What material is required?
2. What elements are of major importance?
3. What aid is available? Other reports? Articles? Persons?
4. What tentative plan should be followed?
5. Are the data accurate? Complete? Useful?
6. Do the conclusions actually grow out of the data and results?
7. What data, results, or conclusions are most important to the report's purpose? To its readers?

Designing

1. What organization will make the report best fulfill its purpose? Most useful and time-saving to the reader?
2. Does the nature of the report require emphasis on the data, the method, the results, the conclusions, the recommendations, or on a combination of any of these?
3. What level of technical usage and material can be understood by the reader?
4. What specific data, examples, details and illustrations are required for clarity of meaning?
5. Is a statement of authorization, purpose, scope required?
6. Does the complexity of the report or the use to be made of it require a table of contents, an index, an abstract?

Application

1. Is the organization sound?
   - A. Is the identity of the subject clear from the beginning? At all points?
   - B. Is the subject advanced by clear-cut stages? Are the relationships between the stages clear?
   - C. Does the conclusion of the report leave the reader with the desired point of view?
2. Is the content adequate?
   - A. Is it complete? Accurate? Clear?
   - B. Are more examples, details, facts, illustrations required for clarity?
   - C. Do the facts require more interpretation?
   - D. Are the major points emphasized?
3. Is the form functional?
   - A. Are all parts easily accessible?
   - B. Are the coordinate and subordinate relationships of the sections indicated by the form?
   - C. Are more organizational devices needed?
4. Is the style acceptable?
   - A. Is the exact meaning conveyed?
   - B. Are the sentences direct and effective?
   - C. Is there any deadwood to be removed?
   - D. Are the mechanics correct?
5. Have standard materials been used?
6. Is the copy neat and attractive?

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